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THE FRENCH METHOD

(OF REPRESENTING NOISE ANNOYANCE)

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16. Abstract

The purpose of this article is to present the French method of evaluating an annoyance, by showing its foundations, its range of application and its limitations.

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THE FRENCH METHOD

(OF REPRESENTING NOISE ANNOYANCE)

Francois Collet[*] and Jacques Delol[**]

The purpose of this article is to present the French method of evaluating an annoyance, by showing its foundations, its range of application and its limitations.

How to pose the problem?

Defining the annoyance caused by aircraft noise, i.e., to analyze and measure it, is a problem which has posed itself in the large Western countries, starting with the beginning of commercial jet aircraft aviation. Is this a simple question of acoustics? The sensation caused by a noise is partly subjective, but only partly. Such a modern music could be considered agreeable for some persons, and could be unpleasant or even unacceptable for others, but in most cases the pleasurable or disagreeable aspect of a noise can be exactly demonstrated, at least on the statistical plane. One of the branches of experimental acoustics has the purpose of establishing the statistical correlation between annoyance sensation and the objective physical characteristics of the noise, for subjects placed under well-determined conditions, without a discussion of physiological effects, which are also studied.

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In the case of aircraft noise, which attacks or surprises persons in their homes in a repetitive manner, we have a psychological and even sociological dimension, which must be added to laboratory conditions. A statistical approach could only verify the hypotheses and eliminate extreme reactions.

Here we will limit ourselves to the French method of a synthetic representation of annoyance, which has allowed the development of systematic plans for exposure to noise in the vicinity of civilian and military airports. These plans constitute important urbanization documents, as another article in this magazine points out.

We will discuss several simple concepts to ensure comprehension of the reader.

Basic terms

First of all, what are the quantities which describe noise?

A pure sound is entire characterized by its intensity and frequency. The intensity is characterized by the acoustic pressure level, conveniently expressed in "physical" or "linear" decibels. The frequency increases the more sharp the sound is, and is measured in hertz (1 hertz = 1 vibration per second).

A complex noise, such as the noise of an aircraft, corresponds to the superposition of several pure sounds. It is characterized by its intensity, which is only a function of the energy involved, but its frequency spectrum can no longer be described by a single number. At this stage we have to recall the following: The acoustic pressure levels are not additive quantities. For example, if an aircraft produces a 100 dB noise at the measurement point, two identical aircraft together will produce a noise of

103 dB. This is a simple consequence of the definition of the decibel which varies as the logarithm of the energy involved, except for a factor.

More exactly, we have the definition:

$$N = 10 \log \frac{I}{I_0}$$

N in dB
I in W/m^2: intensity
I_0 in W/m^2: reference intensity
therefore, if

$$I_3 = I_1 + I_2$$

$$N_3 = 10 \log \left[10^{\frac{N_1}{10}} + 10^{\frac{N_2}{10}} \right]$$

Weighted scales

In order to understand all the debate about aircraft noise, it is necessary to know that the audition sensation does not only depend on the intensity but also on the frequency.

A 40 dB noise at 3,000 hertz is sensed to be just as strong for an average ear as a 60 dB at 100 hertz.

Acoustic researchers recognize this phenomenon well and, for a long time, have been forced to construct units based on the concept of equal sensation of the ear, by weighting the sound level using a correction factor, which itself depends on frequency and intensity.

The corrected units thus developed obey calculation principles which are more or less simple, and can be applied to such a noise to a greater or lesser degree. Also, they are calibrated from slightly different points of view (equal intensity sensation, equal loudness or equal annoyance).

We will mention two weighted units here:

The decibel A

(See weighting curve, Fig. 1.) This is the weighted noise
level unit which is used most by acoustic researchers. This unit
can be applied to light propeller aircraft noise.

The PNdB (perceived noise decibel)

This is the unit which is best suited for jet aircraft noise,
which includes higher frequencies.

This unit, which expresses the PNL (perceived noise level),
is derived from a complex calculation. One obtains a good approxi-
mation by reading off from a noise meter the level in dBN.[1]
The sonometers have filters which attenuate or amplify certain fre-
quencies in order to directly give corrected values for the differ-
ent scales.

Taking into account the duration (of the noise).

The preceding analysis was concerned with instantaneous noise
levels. The passage of an aircraft for a hearer corresponds to a
noise which is more or less brief, depending on the observer's posi-
tion with respect to the trajectory.

The EPNdB (effective perceived noise decibel) measures the
EPNL (effective perceived noise level). It takes into account the
duration of the noise.

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[1] Figure 1 gives the weighting curve for the dBD. One can
easily convert from dBD to dBN using the relationship dBN = dBD + 7.
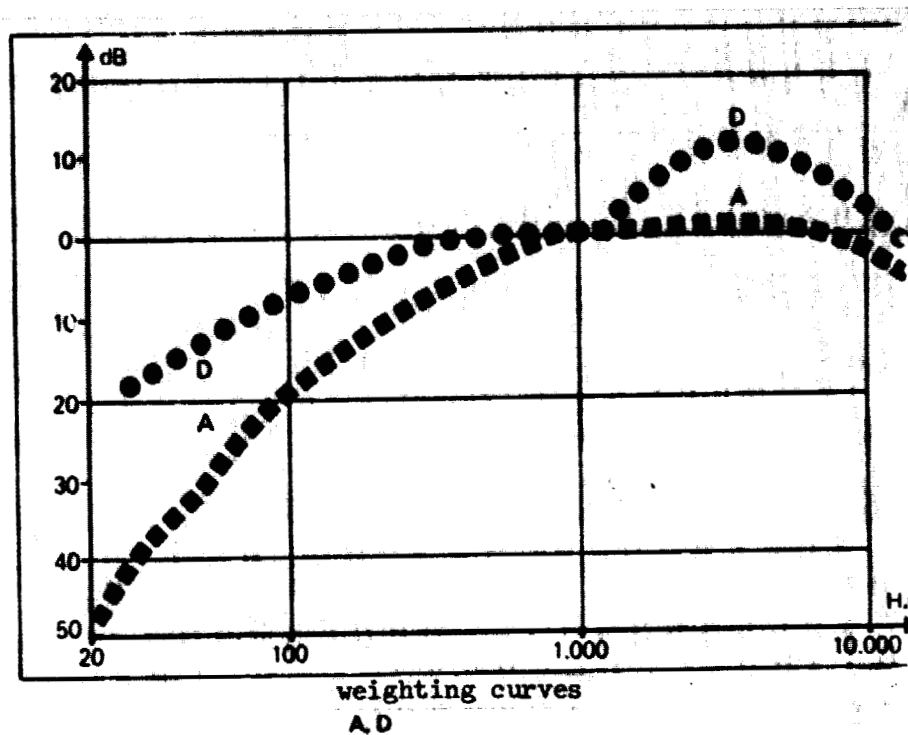
Figure 1.   Weighting curves
A, D

The noise of aircraft

As we have stated, aircraft noise is complex. In the case
of a jet engine, for example, we have to distinguish between the
following:

- The noise of the jet caused by hot gases ejected at the nozzle,
which resembles the noise of a blow pipe, and which is character-
ized by a large frequency bandwidth.

- The noise from the turning components (ventilator, compressor,
turbine), whose frequencies are pure and are a function of the
rotation range of the engine. This noise resembles the noise of
a siren.

These two noises exist simultaneously in any jet engine.
Either of them can dominate depending on the motor technology and

the rotation range. For the most recent engines (airbus), the jet
noise has been for the most part reduced and the other noise sources
are gaining comparable importance. The time at which the aircraft
noise is obviously the most annoying is the moment where they are
near the ground, during takeoff and during approach. Upon takeoff,
the engines operate at full power, but the aircraft rises quite
fast. It is possible to concentrate the annoyance on small areas,
using appropriate procedures. On the other hand, approach before
landing constitutes a very penalizing phase. The aircraft has to
be aligned with the runway axis several kilometers before touch-
down, and it descends along a trajectory with a rather small slope,
with flaps extended. It has to maintain a high engine rotation
rate in order to compensate for aerodynamic drag and in order to
be able to apply full power rapidly if necessary.

Noise exposure: the French index

The index

The annoyance caused at a point by the passage of an air-
craft is a function of the noise level received, expressed in PNdB
or in EPNdB.

This can be measured using a sonometer, or can be calculated
by taking into account the laws of sound propagation, under the
condition that the trajectory, the aircraft type, the engine rota-
tion rate, are correctly identified over every segment of the
trajectory.

But what is the annoyance caused by a succession of aircraft
movements extended over an average day? To what extent does this
depend on the number and the time of aircraft passes? The French
index for noise exposure of aircraft, called the psophic (psophique)
index, globally represents the annoyance with the following hy-
potheses:

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- The global annoyance is a function of the number of aircraft overflights of each type, but does not depend on the overflight times (two aircraft passing overhead at the same time contribute to the index the same amount as two aircraft which pass separated by one hour, for example);

- An aircraft flying overhead at night is considered to be just as annoying as 10 aircraft passing overhead during the day of the same type (motions are considered nocturnal between 22 hours and 6 hours);

- The annoyance is only a function of the peak noise levels.

The index is calculated from:

$$I_p = 10 \log \left\{ \sum_{i=1}^{n} 10^{\frac{N_i}{10}} + \sum_{j=1}^{p} 10^{\frac{N_j + 10}{10}} \right\} - 32$$

N_i is the noise level of daytime aircraft (peak level in PNdB).

N_j noise level of night aircraft (peak level in PNdB) with n passes in daytime and p passes in nighttime for an average day over the year.

It should be noted that the calculation of the psophic index is merely an extension to noises which occur at different moments of the decibel composition law corresponding to the superposition of simultaneous noises.

The index - annoyance correlation

Is the psophic index a good indicator of the annoyance encountered along the sides of airports? Only statistical investigations carried out carefully can verify it. The most important study

and the most interesting one as far as the methodology is concerned is the one carried out in France in 1971 at Orly airport, using the method developed by the technical service of aviation navigation, in collaboration with the French Public Opinion Institute.

Two phases have to be distinguished in the study, which extended over 5,000 persons:

1. The empirical fabrication of an annoyance factor using factorial analysis from responses to graduated questions concerning the presence of the annoyance, its intensity, its frequency, the sound intensity of the noises, the changes in activity (sleep, conversation, television), complaints, etc.

2. The statistical correlation research between the annoyance factor which synthesizes the responses of each individual and the value of the psophic index of his place of residence. The main results of this research are given in Figures 2 and 3. Overall, the annoyance increases with the index, but the dispersion of the responses is large, even for the same location. The annoyance sensation, therefore, is highly diffused. The distribution of the annoyance levels expressed is more significant. As an example, in Figure 3 we can see that among the persons exposed to the index 92, 12% declared that they encountered intolerable annoyance, 60% stated that they encountered a very strong annoyance (very strong or intolerable), 70% stated they encountered at least a strong annoyance, 81% stated that they had encountered an annoyance which was quite strong, 93% expressed a weak annoyance.

These results are very similar to similar inquiries made in foreign countries. Overall, the psophic index appears statistically as a good representation of the average annoyance. However, the very wide deviations of annoyance expressed for the same location, even for very highly exposed areas, demonstrate well that there is no index which could individually predict annoyance, because annoyance is sensed in a diffuse manner.
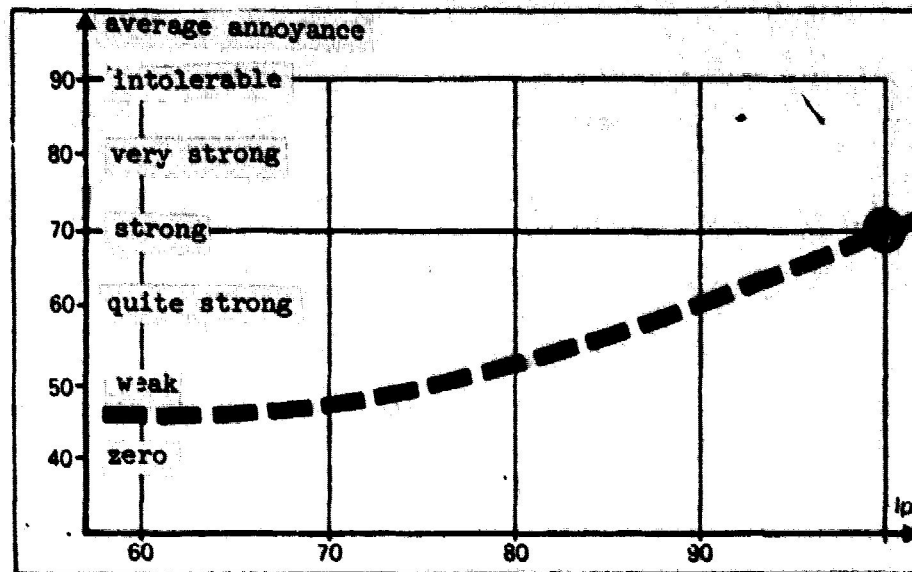
Figure 2

A limitation of the psophic index

The preceding study covered a large airport, around which all of the persons are subjected to the same traffic, either far away or close by.

How can one compare the corresponding annoyance for a small number of movements which each produce an intense noise, and on the other hand, a higher number of movements which produce noises which are more attenuated?

The index-annoyance correlation has never been statistically verified for weak traffic levels. Fortunately, the problem is much less sensitive in this case because it is around the very large airports that large numbers of the population are exposed to the noise.

We would also like to point out that the psophic index seems to reflect poorly the annoyance caused by the noise from light aircraft, and that additional studies are now in process on this topic.

The noise exposure indices

In connection with establishing a policy for dealing with noise limitations around airports, numerous countries have been confronted with the problem of evaluating the annoyance produced by the succession of aircraft movements, in order to have a means of planning the use of the ground between hangars as a function of noise level exposure. This evaluation is based on the definition of an annoyance indicator which is simple and objective, which allows one to associate the characteristic noise variables (sound level, duration, frequency, etc.) and human reactions for these respective repetitive noises.

The annoyance indicators in general are mathematical instruments established from experiments and sociological inquiries around airports.

From an energy accumulation of the various noise levels, they wish to represent the level of noise exposure produced at a given point for a given traffic level using a number (or index). Each aircraft movement is characterized by its maximum noise level in PNdB or its level in EPNdB, and the exposure index to the noise takes into account this level and the number of movements.

The knowledge of these indices at a certain number of points at the site allows one to obtain curves of equal exposure to the noise as a function of the adapted working hypotheses:
- average traffic over a day at the airport (number of movements, aircraft types);
- hourly distribution of the traffic (day, night, season);
- real or anticipated trajectories for a close horizon;
- runway utilization coefficients;
- sound propagation laws in air.

The calibration of these scales of annoyance, or of these curves, is done by correlation of the exposure indices and responses
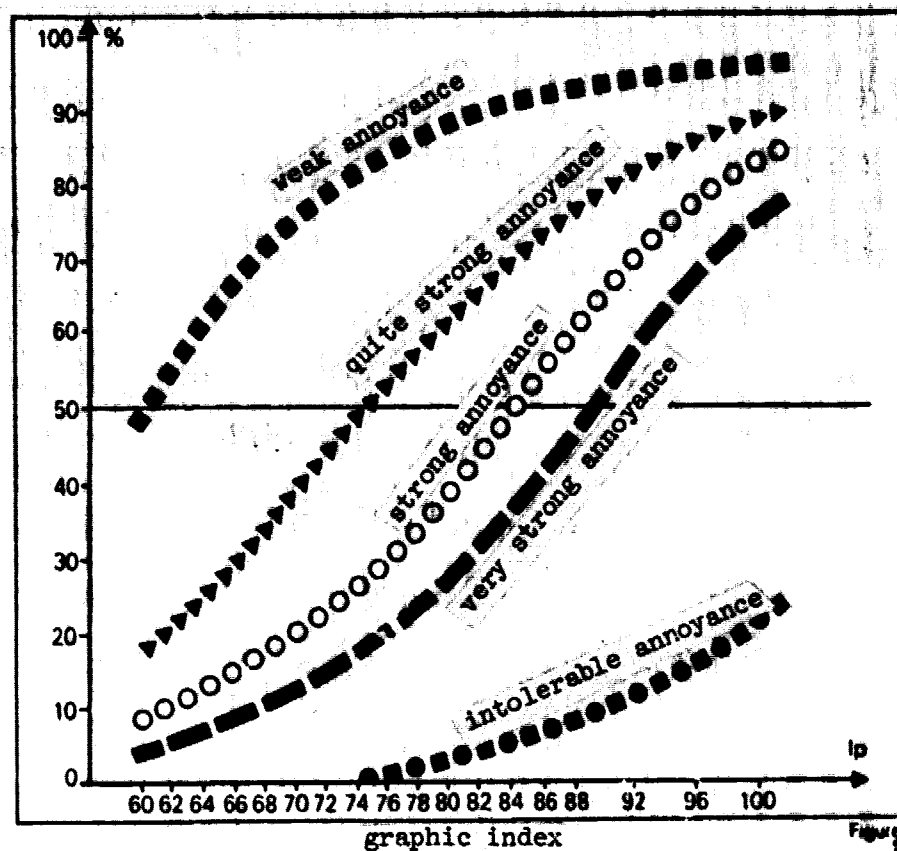
Percentage of persons annoyed as a function
of the noise exposure index

Figure 3

collected during sociological studies. They serve to determine
the limit values of the indices corresponding to noise exposure
levels deemed acceptable, strong or intolerable for any use on
the ground.

Among the valuation methods, we have:

The British method. The NNI is used (numbering and noise
index) based on the cumulative logarithmic maximum levels expressed
in PNdB.

The American methods. The NCR (composite noise index) based
on the PNdB unit and the NEF (prediction of noise exposure) utilizes
the level in EPNdB in each overflight.

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The French method. The psophic index and the isopsophic curves are defined from the PNdB, see below.

The German method. Called the Q factor, which is a synthesis of the preceding methods. It utilizes PNdB or dBA.

The OACI method. This recommends the use of the EPNdB because of the calculation of the ECPNL (equivalent continuous perceived noise level) and the WECPNL (weighted equivalent continuous perceived noise level).

The complexity of calculating quantities such as PNdB or EPNdB, the relative accuracy of the exposure indices have led certain states, especially France, to modify their evaluation method in the sense of a simplification by using a weighting network in order to obtain a good approximation to the PNdB.

The advantage of such a solution is to permit the direct measurement of the exposure level from a simple instrument with sufficient accuracy for taking into account the phenomenon. This evaluation principle is used in all monitoring stations for noise developed by the STNA, and is presently installed in the airports at Nice-Côte d'Azur, Toulouse, Bâle-Mulhouse.

Noise exposure maps

A noise exposure map around an airport is the map representation of zones within which the psophic index exceeds certain given values. In each map we distinguish the following:

- the zone A, where the psophic index is greater than 96 and within which the noise annoyance is considered to be very high;

- the Zone B, where the index is between 89 and 96, within which the annoyance can be considered as strong;

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- the zone C, where the index is between 84 and 89, within which the annoyance can be considered as quite strong.

These limit values have been adapted, taking into account the result of the inquiries mentioned previously. The development of exposure maps to noise requires a calculation model in order to determine the value of the index at any point around each airport.

The data to be taken into account is the average traffic level on each trajectory, and for each aircraft type, because the noise levels are different from one aircraft to another. The trajectories have to be defined in three dimensions and have to be decomposed into segments corresponding to the different motor rotation rates.

The value of the index around the airport is determined for each point using a sufficiently fine mesh. The calculation takes into account the propagation laws and attenuation laws for sound, including the absorption effect by the ground for grazing incidence, and also considers a statistical dispersion coefficient of the traffic around certain trajectories.

The noise exposure maps for French airports have been produced by the Paris Airport Company for Orly, Roissy and the area around Paris. They have been drawn by the aviation base technical service for all of the airports and landing fields of a certain importance, as well as for military airfields. It should be realized that all the noise exposure maps take into account the urbanization documents and are not established based on existing traffic, but on more severe traffic levels than can be predicted at this time.

Conclusion
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The studies which we have described give an approach to the problems which is as objective as possible, considering the fact

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that annoyance is not an exact science.

An effort for objectivity was necessary in order to adapt equitable measures, looking forward to the day when all noisy aircraft will be replaced by quiet aircraft. Knowledge of the annoyance will expand, and certain studies now in progress will be refined. However, a compromise will remain between the accuracy of the knowledge and the equipment to be used, which must remain sufficiently simple. Even if the traffic changes every day, we will never make a noise exposure map for every day of the year!